FIG.1

ANTENNA   TWO TERMINALS

2   1

②   ①   POWER SUPPLY

Z_v V

CONTROL
CIRCUIT

PRIOR ART

FIG.2

THREE TERMINALS

ANTENNA

3   Z_v 4

③   ④

POWER SUPPLY   V   EQUILIBRIUM SYSTEM
MODULATION ELEMENT

STUB RESONANCE BOOST
RECTIFIER CIRCUIT   CONTROL
CIRCUIT

⑤   5

GND

PRESENT INVENTION

FIG. 3

STRIP CONDUCTOR

GROUND PLANE CONDUCTOR
POINT C IS FEEDING POINT OF ANTENNA
POINT F IS CONNECTED TO GROUND
PLANE VIA THROUGH-HOLE

CONTROL
CIRCUIT
CHIP

SIZE (mm)

60

30

5

25

20

THICKNESS 1

INSULATOR

FIG. 4

FIG. 5

(a)

(b)

TANK CIRCUIT — | — LADDER BOOST CIRCUIT

NOTE THAT $c_a >> c_b$

DC OUTPUT $\dfrac{5V_i}{R_i W_o C_i}$

W_o IS RESONANCE ANGULAR FREQUENCY OF TANK CIRCUIT

FIG.6

PRESENCE OR ABSENCE OF TAG RESPONSE SIGNAL

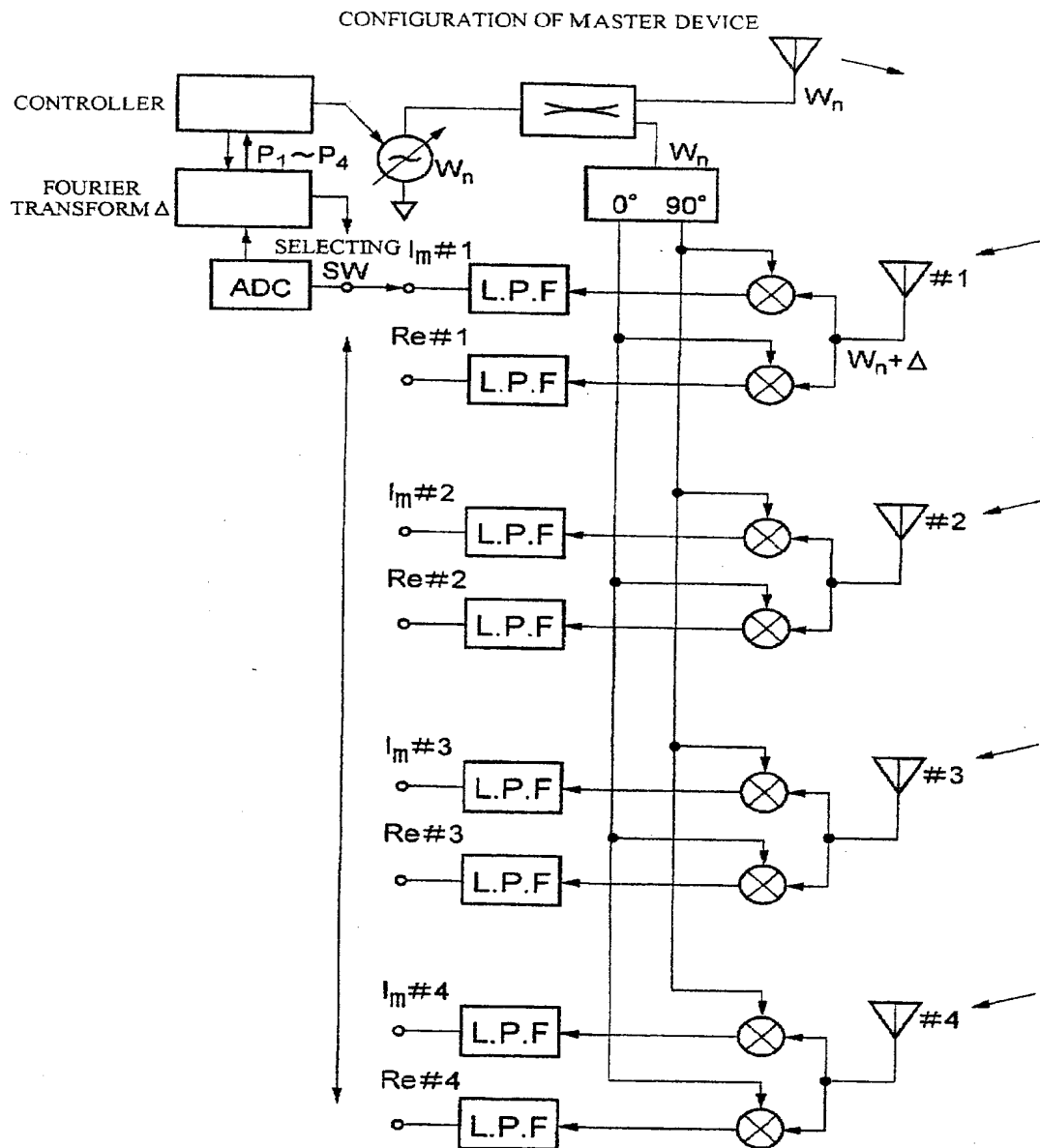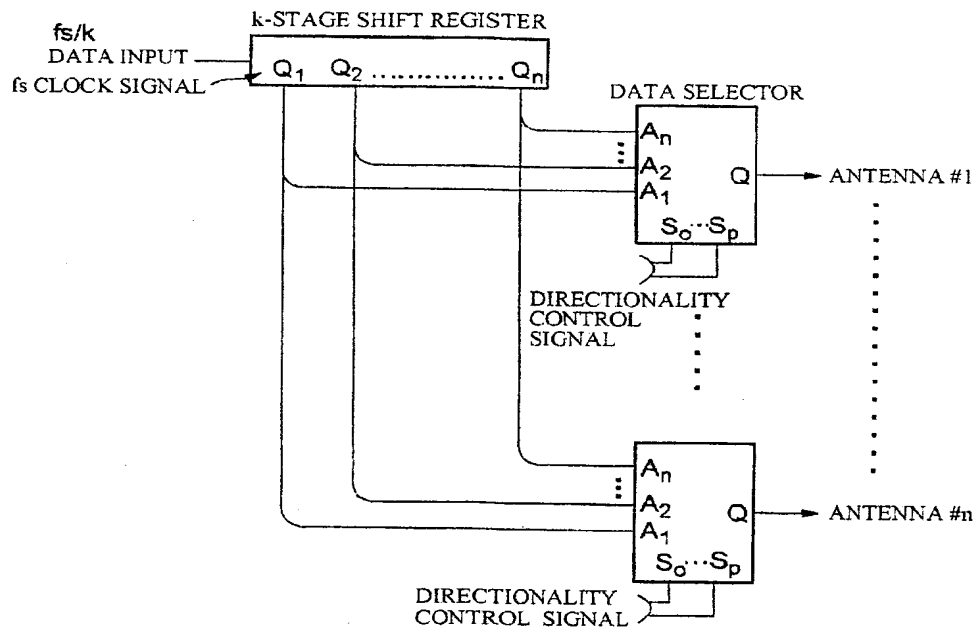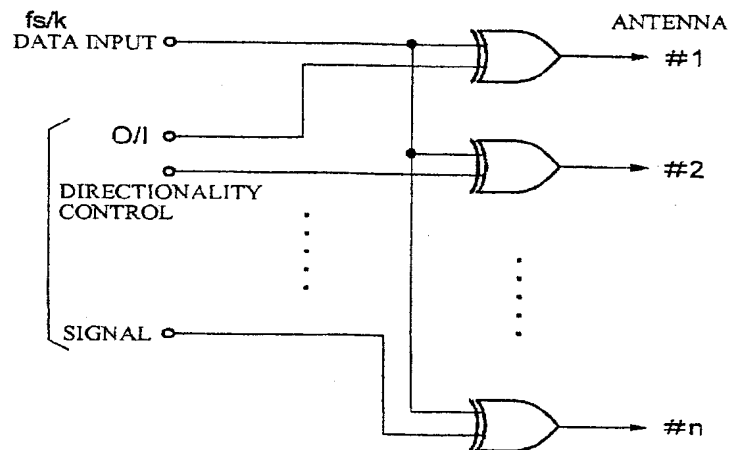|		TAG NUMBER			
		#1	#2	#3	#4
INTERROGATION NUMBER	#1	○	○	×	○
	#2	×	○	○	○

FIG.7

CONFIGURATION OF MASTER DEVICE

FIG.8

FIG.9

FIG. 10

FIG. 11

FIG. 12

FIG. 13

Legend:
— 2ms/SINGLE
■ 2ms/DOUBLE
— 4ms/SINGLE
▲ 4ms/DOUBLE
— 8ms/SINGLE
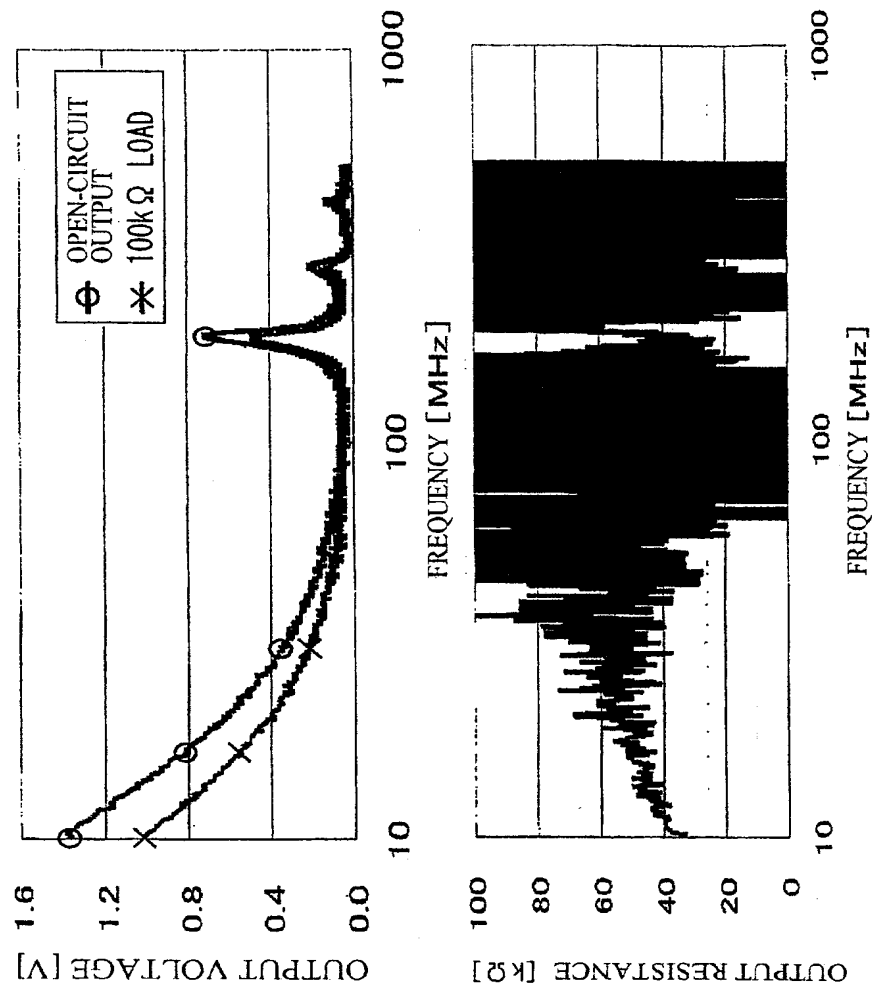● 8ms/DOUBLE

Y-axis: AVERAGE COMPLETION TIME OF READING ALL RFIDS [SEC]
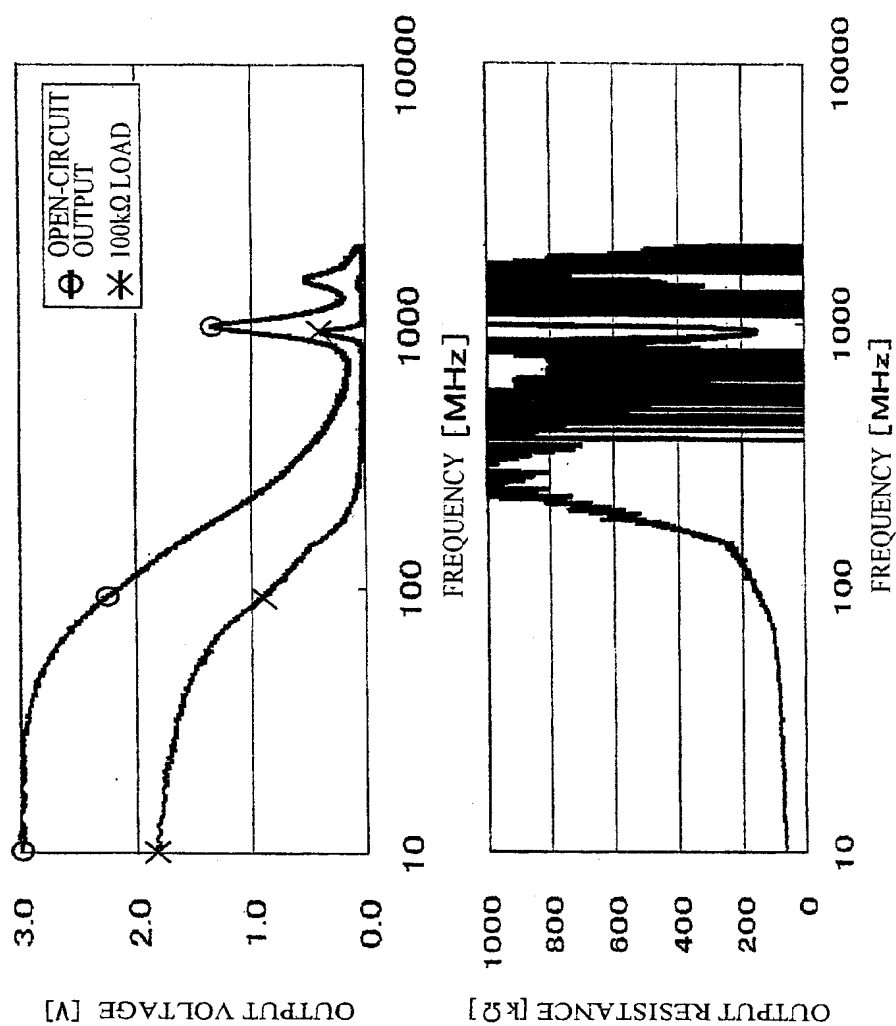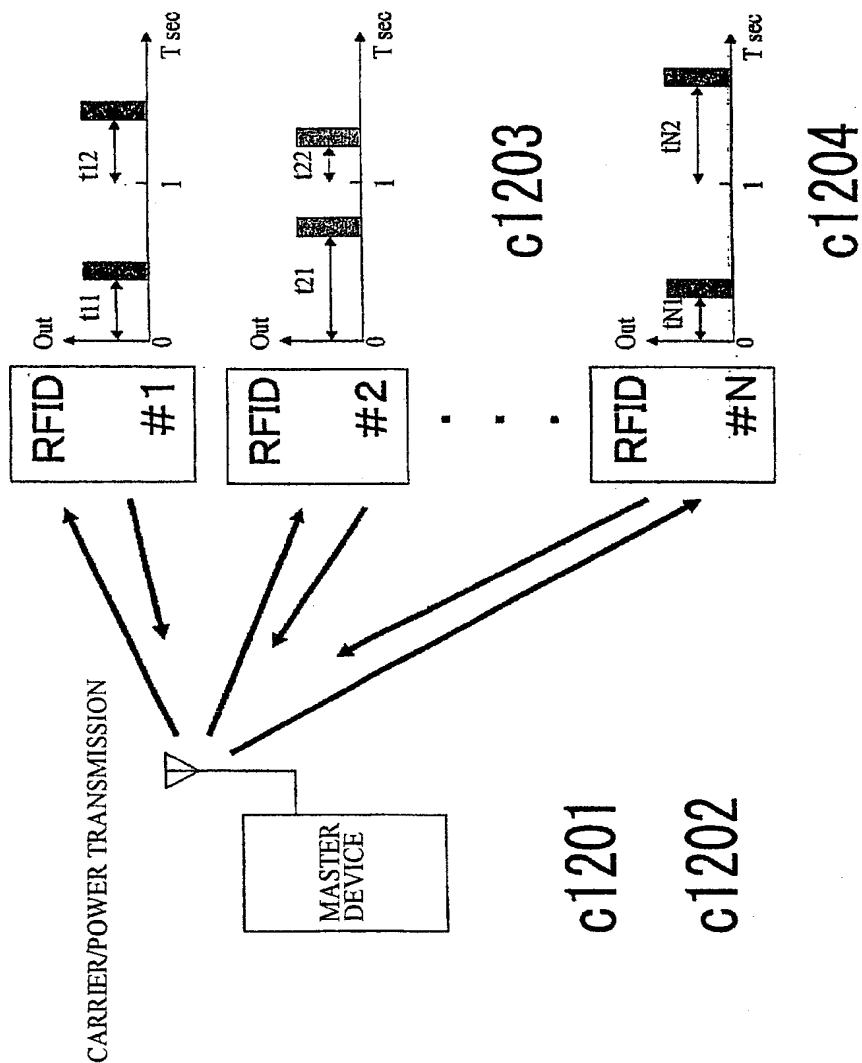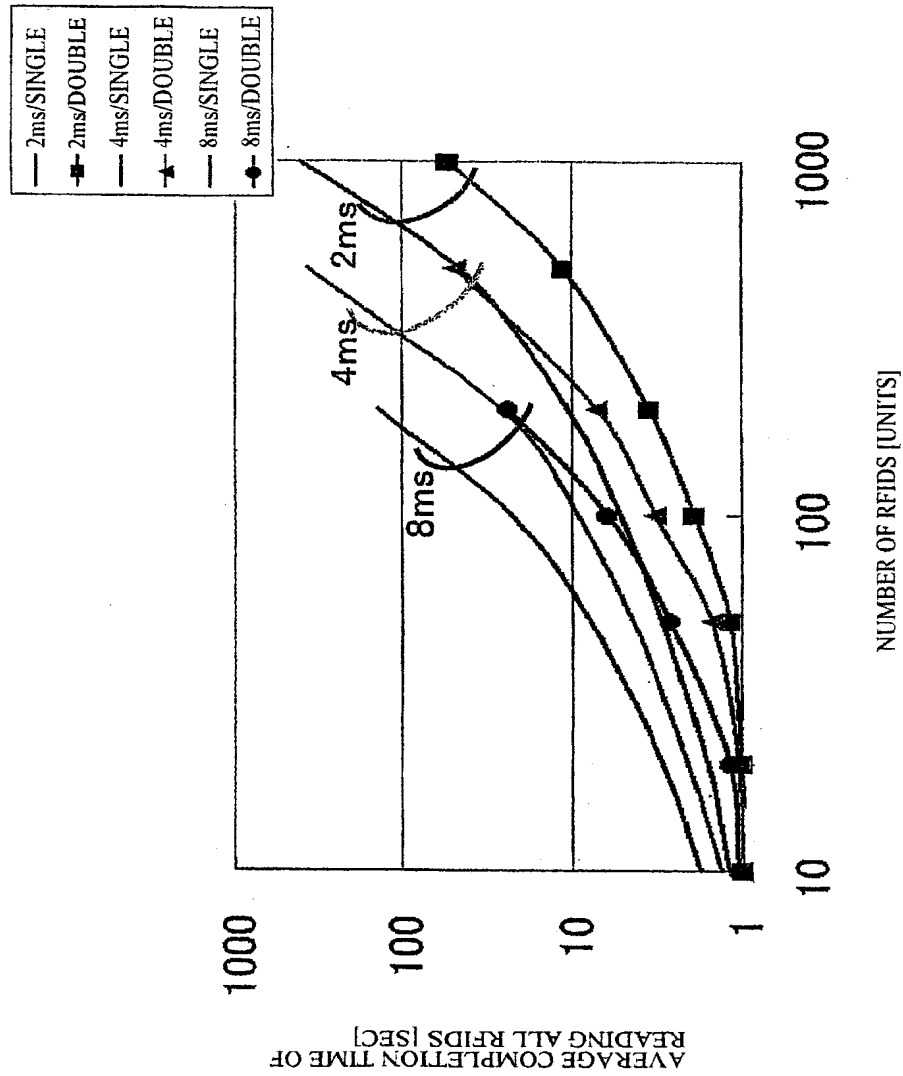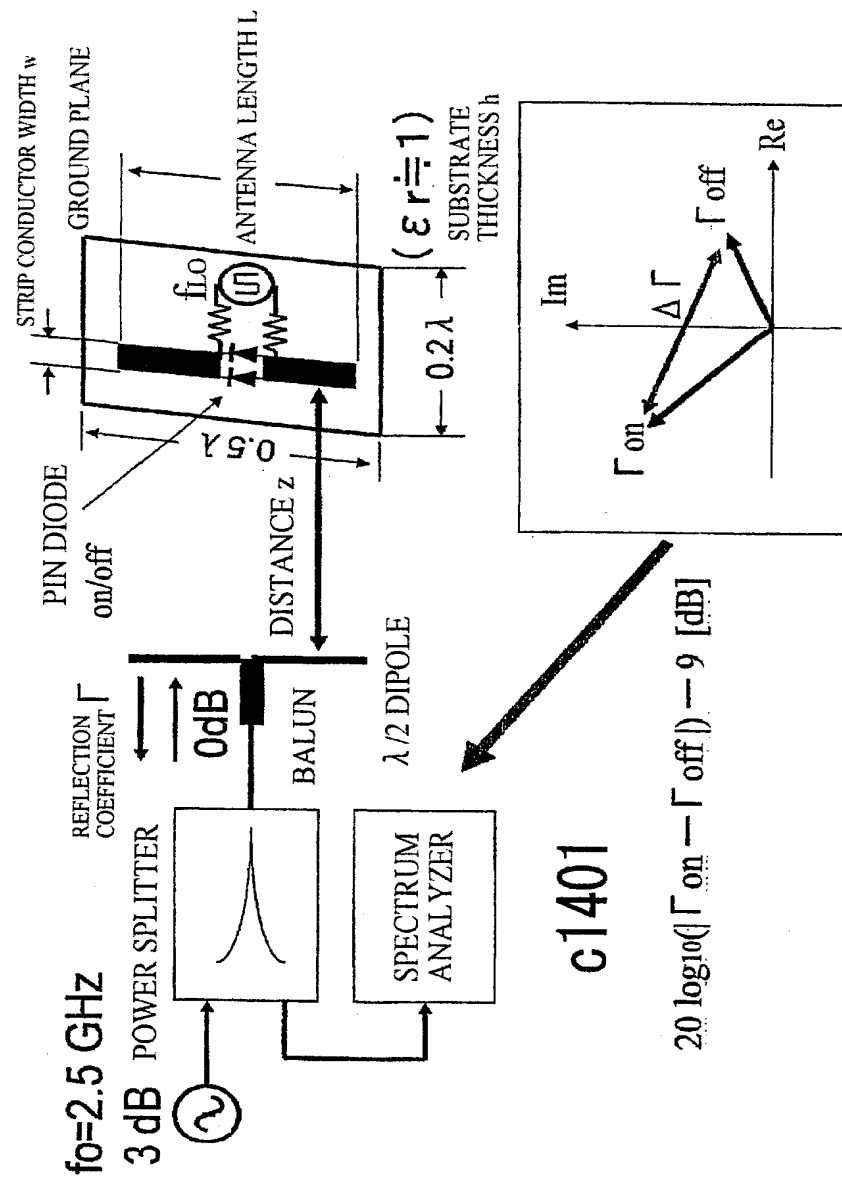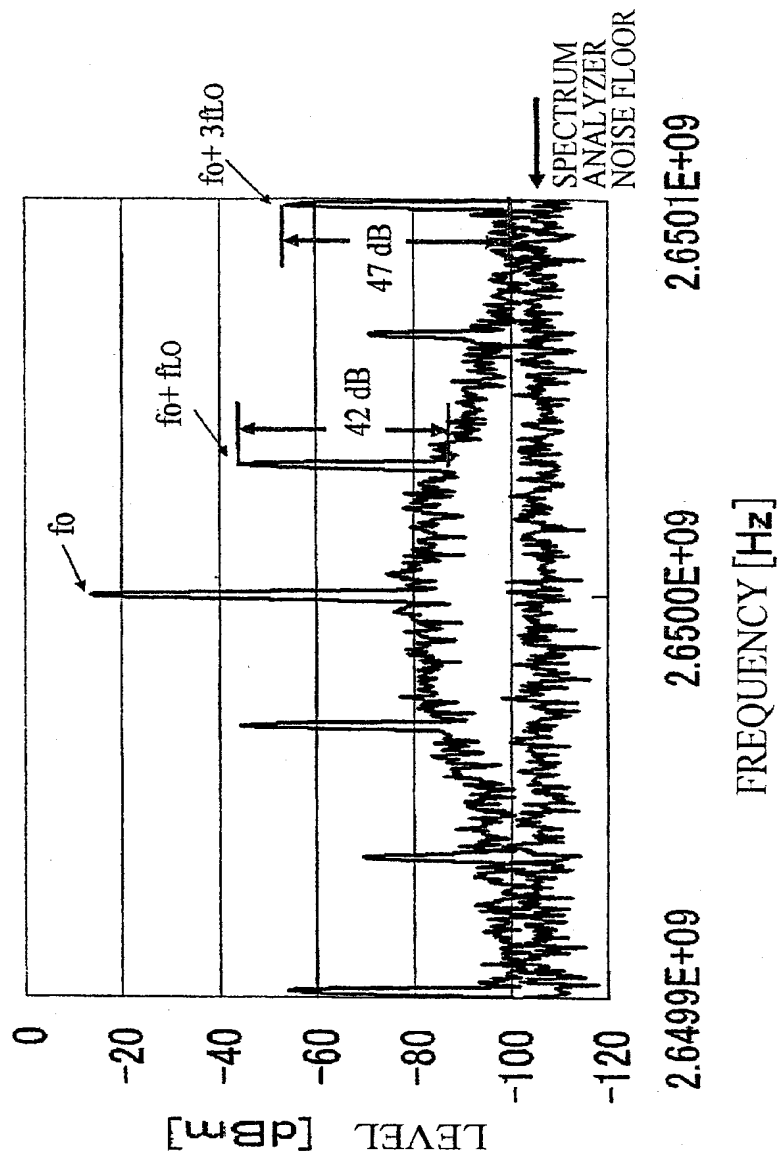X-axis: NUMBER OF RFIDS [UNITS]

FIG. 14

FIG. 15

FIG. 16

FIG. 17

FIG. 18

FIG. 19

FIG. 20

RESPONSE RECEIVER SENSITIVITY [dB]

NORMALIZED FREQUENCY

FIG. 21

FIG. 22

$\omega_n \pm \Delta$ MODULATED WAVE RESPONSE

RFID

CARRIER/POWER TRANSMISSION
FMCW

ω_n

MASTER DEVICE

c2201

#1 #2 #3 #4

L1 L2 L3 L4

c2202

$$L_2 - L_1 = \frac{(P_2(\omega_n + \Delta) - P_1(\omega_n + \Delta)) - (P_2(\omega_{n-1} + \Delta) - P_1(\omega_{n-1} + \Delta))}{\omega_n - \omega_{n-1}} c$$

$$L_3 - L_1 = \frac{(P_3(\omega_n + \Delta) - P_1(\omega_n + \Delta)) - (P_3(\omega_{n-1} + \Delta) - P_1(\omega_{n-1} + \Delta))}{\omega_n - \omega_{n-1}} c$$

$$L_4 - L_1 = \frac{(P_4(\omega_n + \Delta) - P_1(\omega_n + \Delta)) - (P_4(\omega_{n-1} + \Delta) - P_1(\omega_{n-1} + \Delta))}{\omega_n - \omega_{n-1}} c$$
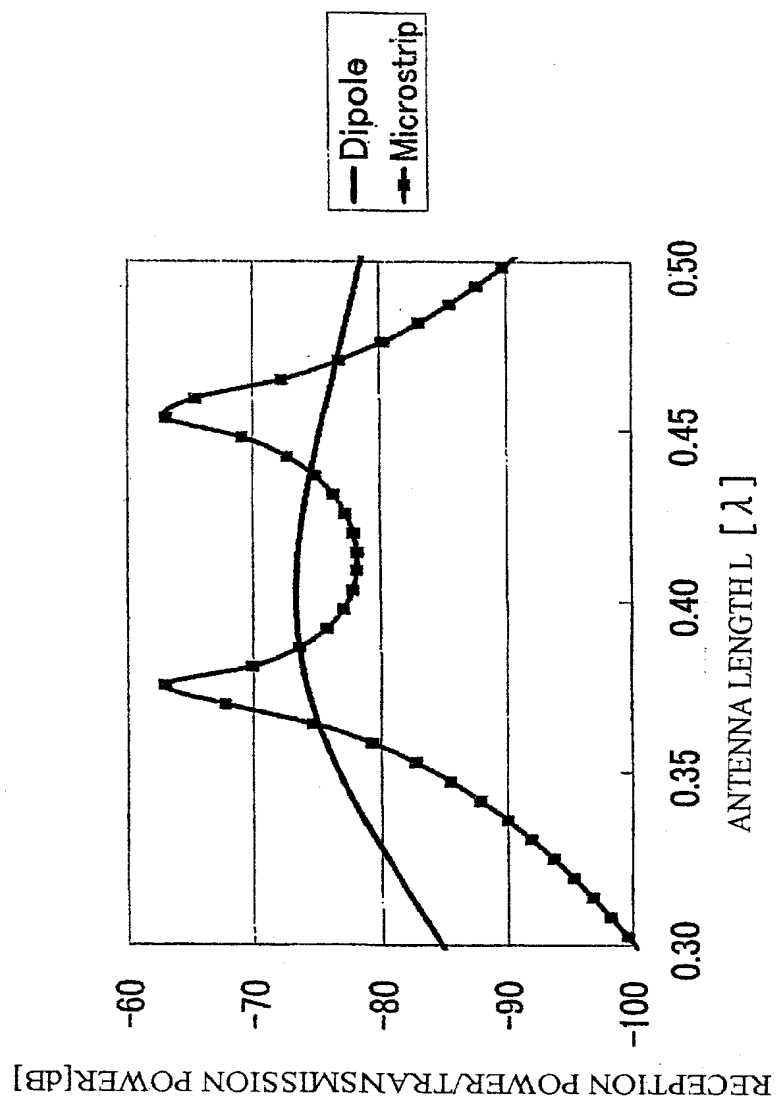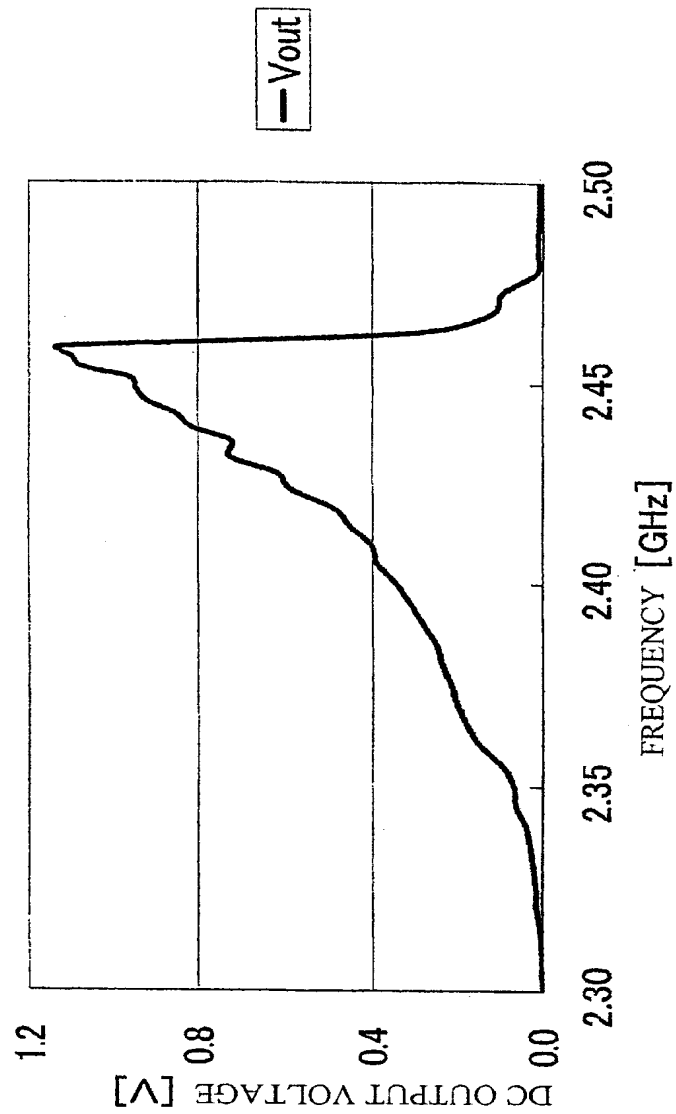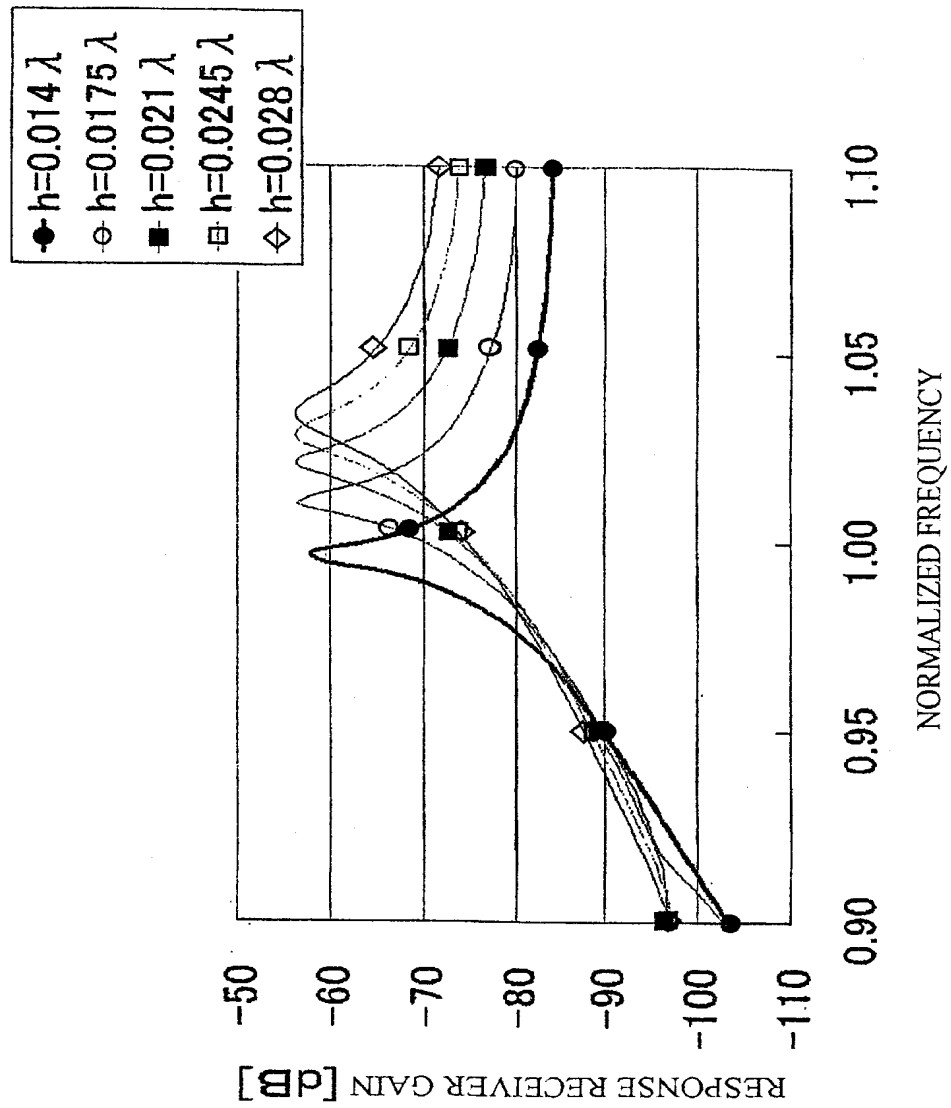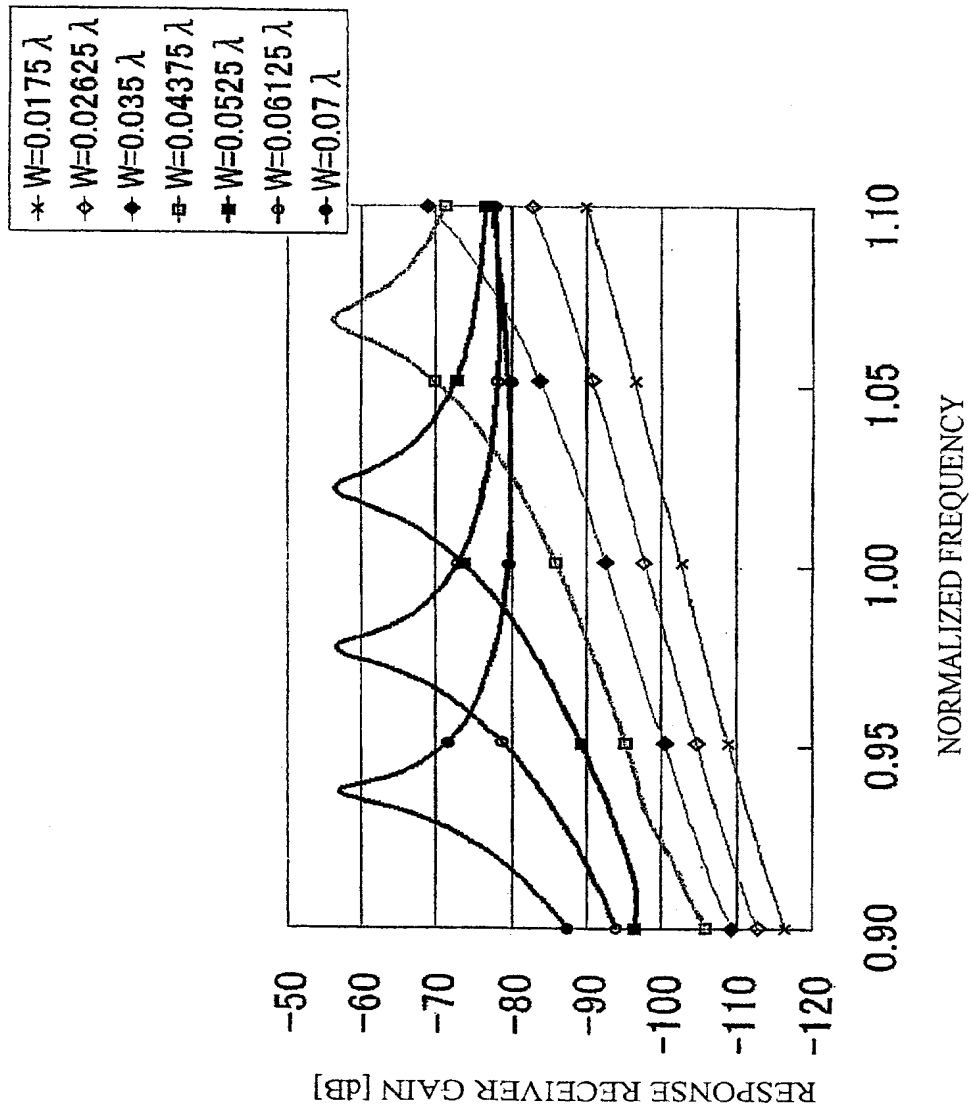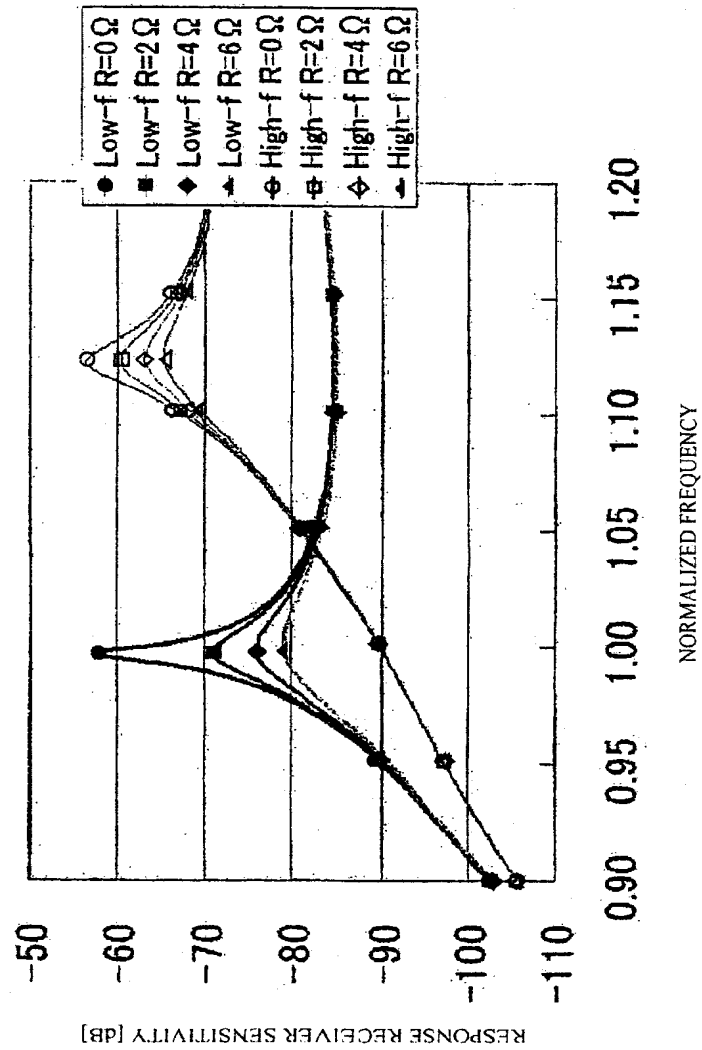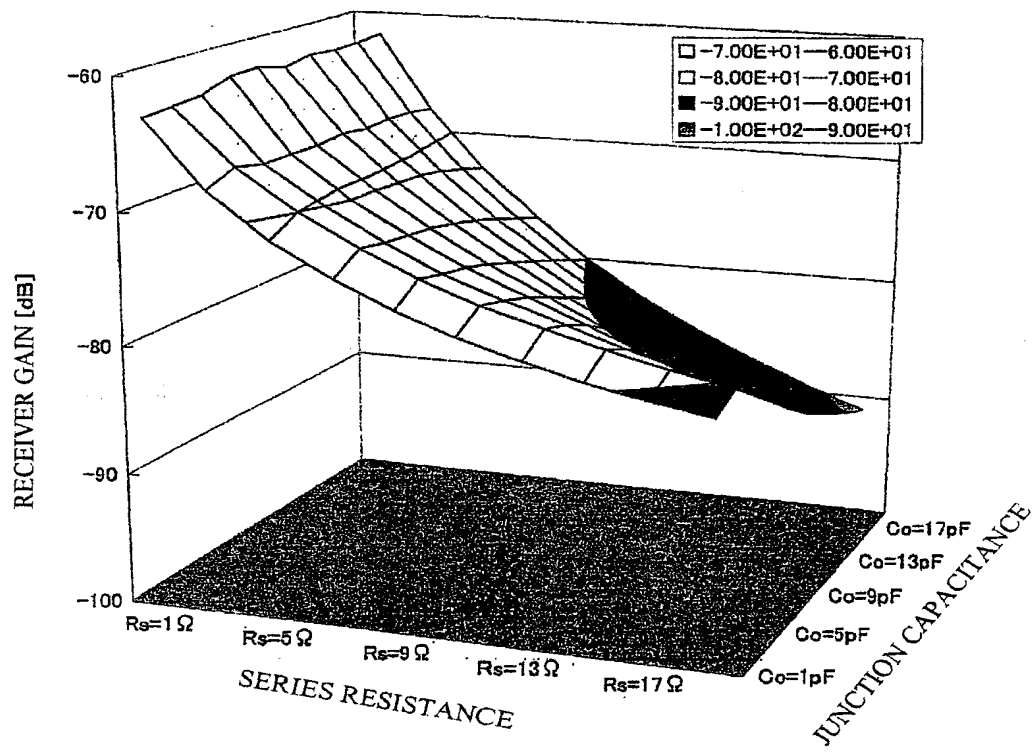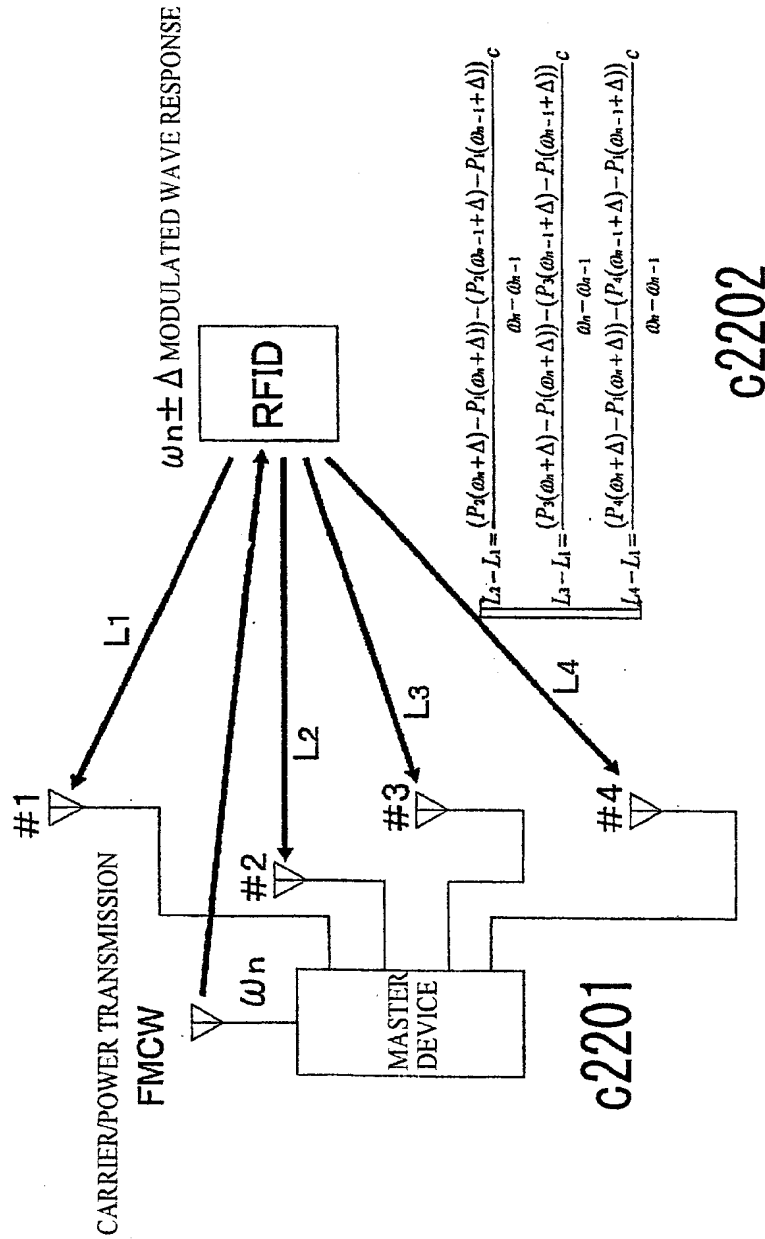
FIG. 23

FIG. 24

FIG. 25

FIG. 26

FIG. 27

FIG. 28
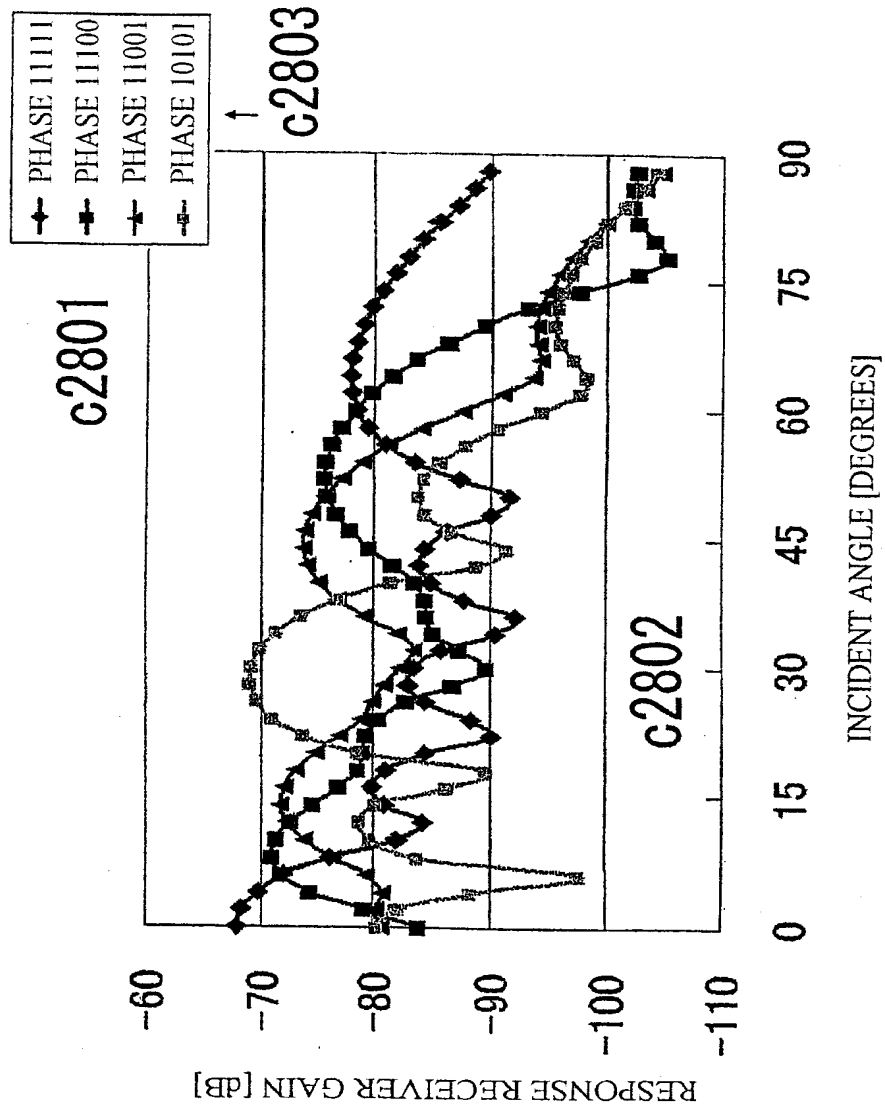
FIG.29

```
real*4 ep(5),x(5),y(5),z(5),xs(5),ys(5),zs(5)
real*4 al(200),bl(200),cl(201)

iij=1234556
f0=0.05
dlh=15.0/f0      ! cm            ](1)
na=16
write(*,10)
format(' Enter the location of x,y,z (cm) : '$)  (2)
read(*,*,end=90) xp,yp,zp

call marray(xp,yp,zp,na,cl)   (3)
do i=2,na+1
    verr=ran(iij)
    al(i-1)=cl(i)*(1.0+(verr-0.5)*0.001)-cl(1)   ! noise 0.1 %  ](4)
end do
write(*,*)   ⊿L(cm)', (al(i),i=1,na)
write(*,*)

call mcycle(na,dlh,al)   (5)

do i=1,5
    ep(i)=1.0e20
end do

do ix=-30,30
    xp=float(ix)*10.0
    do iy=-30,30
        yp=float(iy)*10.0          ](6)
        do iz=-30,30
            zp=float(iz)*10.0

            call marray(xp,yp,zp,na,cl)   (7)
            do i=2,na+1
                bl(i-1)=cl(i)-cl(1)-al(i-1)  (8)
            end do

            call mcycle(na,dlh,bl)   (9)
            er=0.0
            do i=1,na
                er=er+bl(i)**2   (10)
            end do
            do i=1,5
                if (er .lt. ep(i)) then
                    if (i .ne. 5) then
                        do j=5,i+1,-1
                            ep(j)=ep(j-1)
                            x(j)=x(j-1)
                            y(j)=y(j-1)
                            z(j)=z(j-1)         ](11)
                        end do
                    end if
                        ep(i)=er
                        x(i)=xp
                        y(i)=yp
                        z(i)=zp
                    go to 30
```
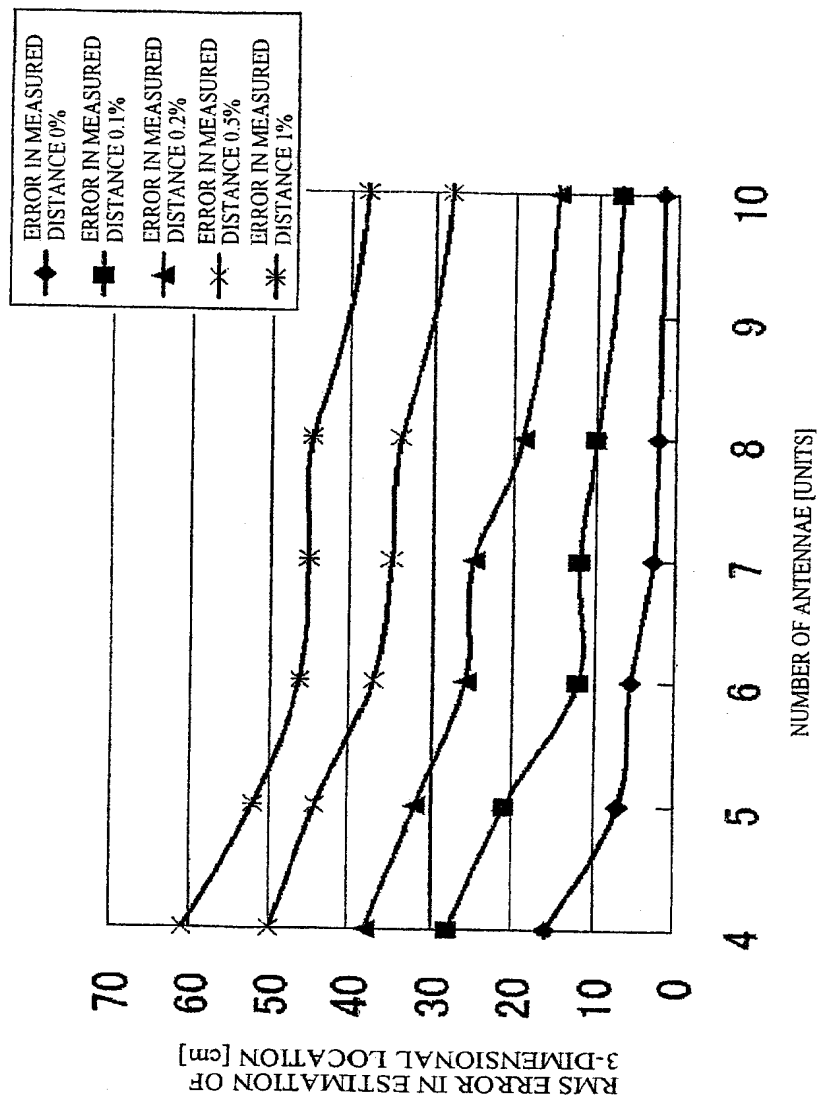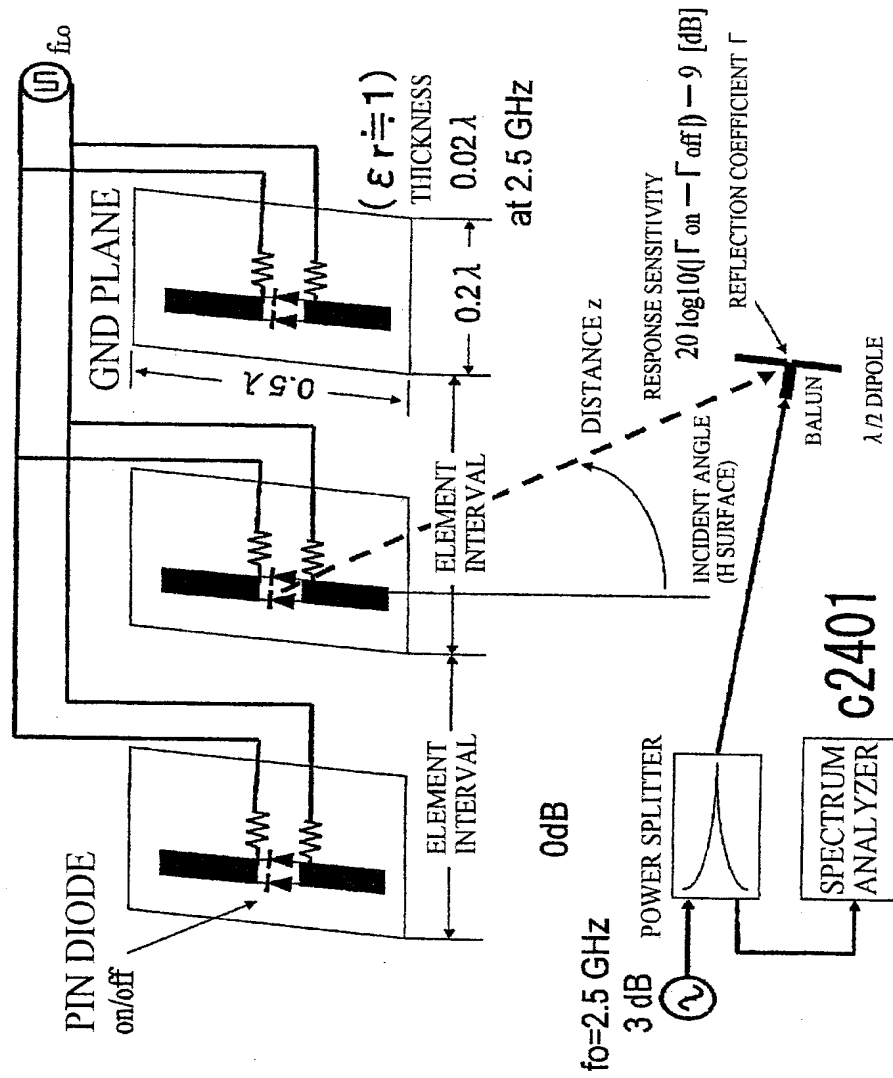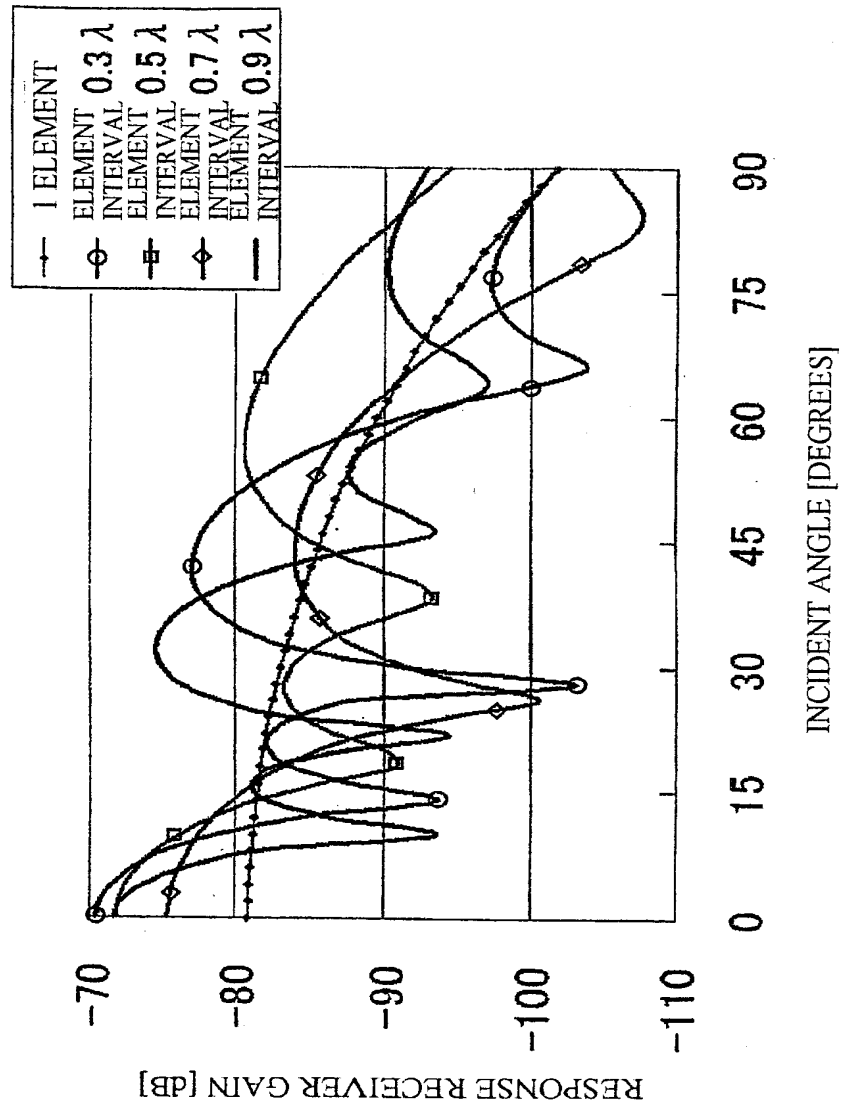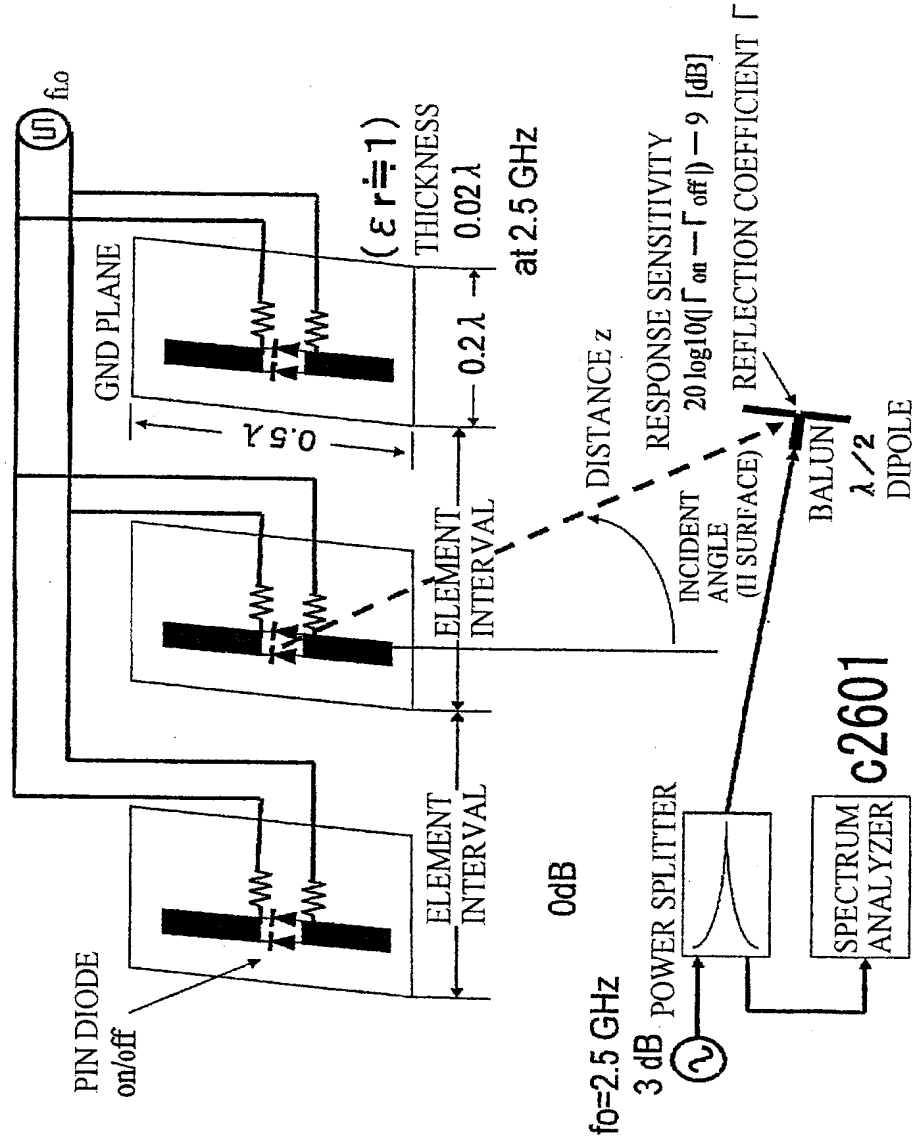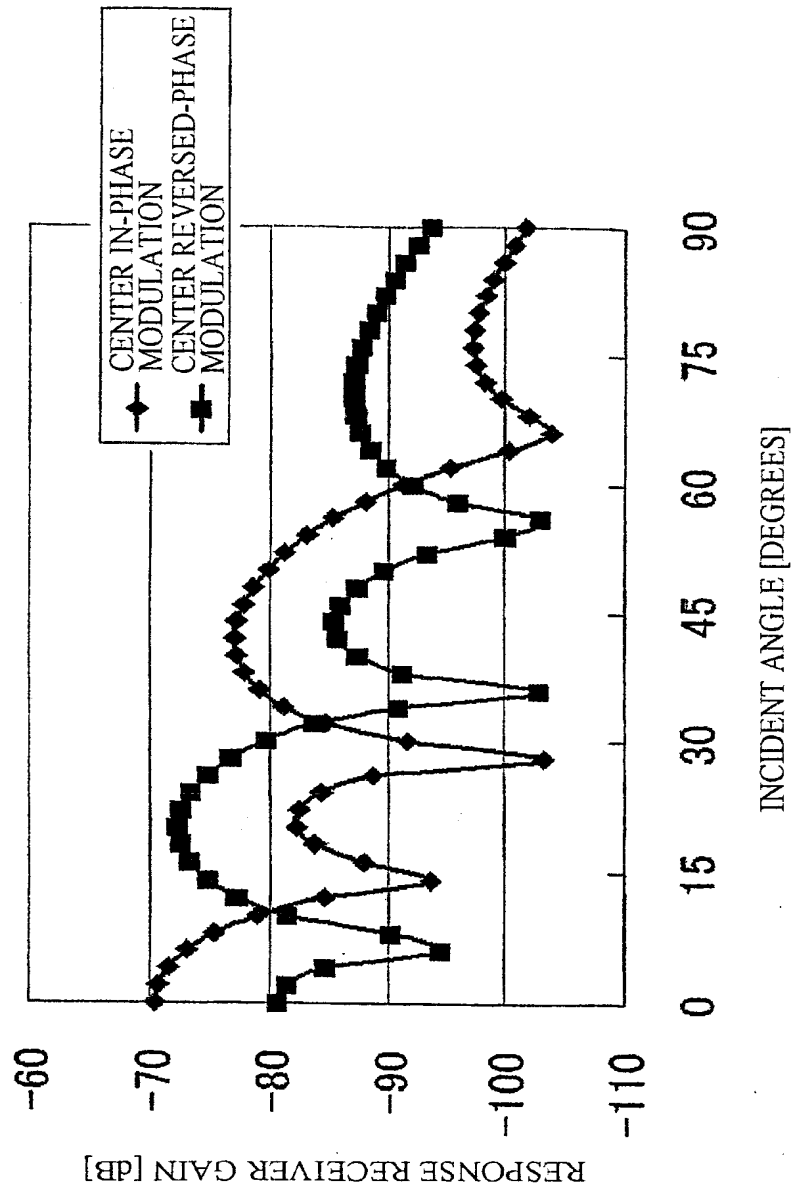
FIG.30

```
                    end if
                end do
                continue
            end do
        end do
    end do

    do i=1,5
        xs(i)=x(i)
        ys(i)=y(i)
        zs(i)=z(i)
    end do

    write(*,*) ' RMS error (cm)          x              y          z   (12)
    do i=1,5
        write(*,*) sqrt(ep(i)/float(na)),x(i),y(i),z(i)
    end do

    do m=1,5                                                              (13)
        x0=xs(m)
        y0=ys(m)
        z0=zs(m)
    do ix=-15,15
        xp=float(ix)+x0
        do iy=-15,15
            yp=float(iy)+y0
            do iz=-15,15
                zp=float(iz)+z0

                call marray(xp,yp,zp,na,cl)
                do i=2,na+1
                    bl(i-1)=cl(i)-cl(1)-al(i-1)
                end do

                call mcycle(na,dlh,bl)
                er=0.0
                do i=1,na
                    er=er+bl(i)**2
                end do

                do i=1,5
                    if (er .lt. ep(i)) then
                        if (i .ne. 5) then
                            do j=5,i+1,-1
                                ep(j)=ep(j-1)
                                x(j)=x(j-1)
                                y(j)=y(j-1)
                                z(j)=z(j-1)
                            end do
                        end if
                        ep(i)=er
                        x(i)=xp
                        y(i)=yp
                        z(i)=zp
                        go to 35
                    end if
                end do
```

FIG.31

```
              continue
          end do
       end do
  end do

  end do
  write(*,*)
  write(*,*) sqrt(ep(1)/float(na)),x(1),y(1),z(1)    (14)

  write(*,*)
  go to 20

  stop
  end

  subroutine marray(xp,yp,zp,na,cl)

  real*4 cl(1)

  cl(1)=sqrt(xp*xp+yp*yp+(zp+50.0)**2)
  do i=2,na+1
     ixx=i/3
     iyy=i-ixx*3
     xm=float(ixx-1)*50.0-10.0
     ym=float(iyy-1)*50.0+10.0
     cl(i)=sqrt((xp-xm)**2+(yp-ym)**2+zp*zp)
  end do

  return
  end

  subroutine mcycle(na,dlh,al)

  real*4 al(1)

  do i=1,na
     continue
     if (al(i) .gt. dlh) then
        al(i)=al(i)-dlh
        if (al(i) .le. dlh) go to 46
        go to 40
     end if
     continue
     if (al(i) .lt. -dlh) then
        al(i)=al(i)+dlh
        if (al(i) .ge. -dlh) go to 46
        go to 45
     end if
     continue
  end do

  return
  end
```

FIG.32

```
Enter the location of x,y,z (cm) :  152,-203,56
  ⊿L(cm)    67.67562      -38.21133      -1.487458      39.09471
 -69.24731     -27.88023      16.30007     -91.74537     -46.11990
  0.9732714    -102.0754     -54.30361     -5.570741     -98.28325
 -51.46763      -3.269386

  RMS error (cm)        x            y            z
  0.6834297      150.0000     -200.0000      60.00000
  0.8562734      150.0000     -190.0000      50.00000
  1.116775       150.0000     -200.0000      50.00000
  1.163736       160.0000     -230.0000      70.00000
  1.216863       160.0000     -220.0000      60.00000

  8.4395386E-02   152.0000     -203.0000      56.00000

Enter the location of x,y,z (cm) :  22,123,-89
  ⊿L(cm)   5.506481      57.46710      16.50204      -17.27929
  55.74849       14.06553     -20.41722      66.89948      28.19106
  -2.332703      89.04320      55.22502      29.83902     119.4193
  90.37129       69.39222

  RMS error (cm)        x            y            z
  1.445567       20.00000     130.0000     -90.00000
  1.754374       20.00000     130.0000    -100.00000
  1.951296       20.00000     120.0000     -80.00000
  2.345274       20.00000     120.0000     -90.00000
  2.709345       20.00000     140.0000    -100.0000

  6.2024966E-02   22.00000     123.0000     -89.00000

Enter the location of x,y,z (cm) :  60,161,5
  ⊿L(cm)  -23.45399      32.54938      -13.85323      -57.41031
  21.66080      -27.96993     -77.36571      22.85288     -26.38201
  -74.96463      36.05470     -9.367880     -51.50449      59.00156
  18.86572      -15.62937

  RMS error (cm)        x            y            z
  1.358104       60.00000     160.0000      10.00000
  1.400364       60.00000     160.0000     0.0000000E+00
  1.561480       60.00000     170.0000     0.0000000E+00
  1.779230       60.00000     170.0000      10.00000
  1.850774       60.00000     150.0000      10.00000

  4.4650473E-02   60.00000     161.0000      5.000000

Enter the location of x,y,z (cm)
```